NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A COMBAT SIMULATION ANALYSIS OF THE AMPHIBIOUS ASSAULT VEHICLE IN COUNTERMINE OPERATIONS

by

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September 1999

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE September 1999	3. REPORT TYPE AND DATES COVERED Master's Thesis	
4. TITLE AND SUBTITLE A COMBAT SIMULATION ANALYSIS OF THE AMPHIBIOUS ASSAULT VEHICLE IN COUNTERMINE OPERATIONS			5. FUNDING NUMBERS
6. AUTHOR(S) Fambro, Dillard H. III.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING / MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for pubic release; distribution is unlimited.			12b. DISTRIBUTION CODE

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14. SUBJECT TERMS Amphibious Assault Vehicle, Janus Simulations, Mine Warfare			15. NUMBER OF PAGES 74
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

Approved for public release; distribution is unlimited

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Submitted in partial fulfillment of the
Requirements for the degree of

MASTER OF SCIENCE IN APPLIED MATHEMATICS

from the

NAVAL POSTGRADUATE SCHOOL
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ABSTRACT

The purpose of this thesis is to evaluate the effectiveness of an Amphibious Assault Vehicle (AAV) as a mine countermeasure in the surf zone and beach zone (sz/bz). In order to show the utility of these approaches, this thesis presents results from three different scenarios. Scenario one provides a baseline and is conducted with the amphibious landing force moving onshore with no minefield breaching operations being conducted. Scenario two encompasses a more traditional method of minefield breaching. Scenario three will use AAVs only to breach the surf zone and beach zone minefields. The focus will be placed on the number of mines neutralized as well as the number of assets killed.

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I. INTRODUCTION

A. RESEARCH OBJECTIVE

The purpose of this thesis is to analyze the effectiveness of the Amphibious Assault Vehicle (AAV) as a mine countermeasure vehicle in the surf zone and beach zone, and to compare this concept with the current naval capabilities of minefield breaching.

B. BACKGROUND

1. Mines and Their Employment

The history of mine warfare in the United States dates back to the American Revolution and David Bushnell's famed experiments with underwater explosives and submersibles. In the summer of 1777, Bushnell cabled together a double line of contact mines (contact-primed powder kegs) to attack the British frigate Cerverus off the coast of Connecticut. The Cerverus survived, but only after a schooner was destroyed along with its crew while attempting to haul the mines. Bushnell's early attempts at mining met with little success, though the attempt in this case turned out to be what was significant, not the failure of the mines to inflict relevant damage. [Ref. 1]

What mines do. Mines sink or damage ships, destroy or incapacitate vehicles, and kill or maim individuals. Based upon demonstration of these very real effects from the use of mines, there are the psychological threats of a lurking, unseen weapon. It is a grave mistake to underestimate the psychological impact of mines. [Ref. 2] Mines are essentially strategic weapons, or tactical weapons that are applied through simple means to bring about destruction for strategic means. They are used to delay military operations, logistic support, and deny sea-lanes. Mines placed within beaches, forests, and other landmasses intended to inflict casualties to ground forces are called anti-personnel mines. These land areas, if strategically occupied with mines, are called minefields. They are used to slow or halt the progress of an adversary.

Mines deployed within sealanes, surf zones, or very shallow water are generally called naval mines. The depths for which naval mines are deployed is as followed:

-Deep water: greater than 200 feet
-Shallow water: from 40 to 200 feet
-Very shallow: from 10 to 40 feet
-Surf zone: from high water mark to 10 feet
-Beach zone: from inland to high water mark

The classification of naval mines is determined by how they are deployed- floating, moored, or buried. [Ref 3]

For the Navy, naval mines are large and easy to find but the consequence of a mine striking a Naval vessel can be the loss of a vast amount of supplies or a major combat element. Furthermore, a single mine incident could result in the loss of many sailors. Consequently, the Navy's goal is to find and neutralize every mine, everytime. For the Army, land mines are small and more difficult to find and the loss is usually less significant. It can be the loss of one vehicle or a lesser amount of supplies.

Considering just land mines, there are two basic types; anti-tank, which attack vehicles, and anti-personnel, which attack individuals. Although it is not an exact comparison, anti-ship and anti-tank mines are similar; the mines are larger, easier to detect and safer to neutralize. Countermine operations at sea do not have an equivalent to the anti-personnel mine found on land. Because of these anti-personnel mines, the problem on land is much more difficult. Anti-personnel mines are deliberately employed to complicate countermine operations. They are often employed with hard-to-see trip wires. They are not targeting a system, they are targeting the man who is trying to eliminate an obstacle and they do a great job. They are small, well hidden, and inexpensive and even once discovered, dangerous to neutralize. [Ref. 4]

Land mines are typically classified according to their firing mechanism- controlled, contact, magnetic, acoustic, pressure, and any combination thereof. They are used to damage all that comes into contact with them - personnel, tanks, trucks, etc.

Landmines like so many other technological advancements first considered inhumane, became an accepted part of warfare another occupational hazard of the infantryman. So long as death or maiming were confined to the combat soldier or Marine, there was no outcry. That all changed when, during the latter part of this century, warring factions on several continents began using antipersonnel landmines to target and terrorize civilian populations. In Sherman's words, this was not war, but murder. [Ref. 4] The U. S. Army catalogues all mines by size, origin, firing mechanism, weight, depths deployed, explosive content, degree of lethality. There are approximately 100 million mines deployed in the world today.

2. Mine Countermeasures Historical Perspective

During the 19th Century, naval forces of several nations, particularly those nations with little or no navies, easily proved the operational effectiveness of mines and mining in stopping or redirecting larger assaulting fleets. Over 40 ships were lost in Charleston, South

Carolina's harbor during the Civil War due to the use of mines. With the rising increase of mines, the Union Navy Department ignored the increasing problem that would plague the Navy. Throughout the war, individual naval officers developed successful countermeasures as the situations arose. These officers' assiduous attention to minehunting and to development of ship protection devices damned the torpedoes they faced in combat, and led directly to their victories. These individuals, were also the ones, at great hazard to their careers, who were responsible for keeping mine and torpedo warfare alive in the Navy. [Ref. 5]

Throughout out the early 20th Century, the production and use of mines increased in deadliness and popularity. As a result, by 1910, most navies except the United States Navy had created significant mine countermeasures (MCM) forces and fleets to combat the menace. Heavy use of German mines during World War I forced a reevaluation of that policy, and the U.S. Navy quickly assembled an MCM force of old fleet tugs and new-construction minesweepers manned primarily by reserves. [Ref. 5]

In the years between the two world wars, mine technology advanced while countermeasures were largely ignored. Minesweeping was a collateral duty among naval officers with little emphasis on being proficient. As a

result, by the time war in Europe again erupted, few U.S. naval officers had learned much about the real capabilities of modern mines. The best we could do, noted one officer faced with the problem in the spring of 1940, was to recognize the probability of mines and pretend that we could sweep. The problems encountered with mine warfare were considered too hard. [Ref. 5]

Many of the challenges now associated with combat MCM are solvable. Technological developments in amphibious and shallow-water mine warfare are ongoing, as are tactical reevaluations. The largest distinction between land and sea countermine operations is the scope of the problem sheer numbers of munitions. Mine warfare has been integrated into the command structure. Mine warfare is not overly difficult problem, but it is a more difficult problem than some decision-makers would like to believe. The major lesson we should learn from the past 90 years of our experience is that we need good hardware, software and personnel. [Ref. 5]

C. AMPHIBIOUS ASSAULT VEHICLE

The Amphibious Assault Vehicle (AAV) is an armored assault amphibious full-tracked vehicle. There are currently three versions of the AAV: AAV Command Model 7A1 (AAVC7A1), AAV Personnel Model 7A1 (AAVP7A1), and AAV Recovery Model 7A1 (AAVR7A1). This thesis will focus on and

use in simulations the AAVP7A1 (it will be abbreviated AAVP). This vehicle carries troops in water operations from ship to shore, through rough water and surf zone. It also carries troops to inland objectives once ashore. FMC Corporation began manufacturing the vehicle in 1979, with its first production vehicle in 1983. The AAVP weighs between 46,000 pounds and 61,000 pounds, from unloaded to fully loaded with a mine clearance kit. One component of the mine clearance kit is a line charge that extends 100 meters when fired. With its 171 gallon fuel tank, it can carry twenty-one combat equipped troops or 10,000 pounds of cargo up to 300 miles at 25 mph on land or 7 hours at 2600 rpm in water. The AAVP is 13.5 feet long, six feet wide, and five and a half feet high. It has an armament of a caliber .50 machine gun and a 40-MM machine gun. It will be assumed that the detonating (explosive) section of the line charge is 100 meters long. Figure is of the AAVP7A1.

Figure 1

D. ORGANIZATION

This thesis is organized into five chapters, including this introduction. Chapter II addresses the simulation modeling process and the Janus program. Chapter III describes the construction of Operation Kernel Blitz 99 in Janus. Chapter IV conducts a statistical analysis of the numerical data obtained from the results of the scenarios. Chapter V summarizes and concludes the findings and puts forth recommendations drawn from this research.

II. MODELING PROCESS

A. SIMULATION MODELING

Models and war games have long played a role in defense decision making. The Chinese, Indians, and Japanese apparently had war games 3,000 to 4,000 years ago. [Ref. 6] Simulation modeling allows the user or users to analyze various scenarios (whether real world or not) without the cost of building or destroying equipment, buildings, or injuring individuals. A list of the advantages, disadvantages, and pitfalls of simulation is as follows:

**ADVANTAGES*

-Can model complex real-world systems with several stochastic elements

-Performance of an existing system can be evaluated under different operating conditions

-Alternative systems or operating policies can be compared

-Allow better control on experimental conditions

-Simulation experiments are reproducible making it possible to study long-range effects in a short time

**DISADVANTAGES*

-Each run of a simulation only gives an estimate of true system performance

-Requires statistical methods to give more precise results

-Simulation models can be expensive and time-consuming to develop

-It is often difficult to validate the model

-Large volume of output data and attractive graphics often mask problems in the inherent assumptions

PITFALLS

-Failure to define the objectives of the study

-Inappropriate level of detail

-Not just an exercise in computer programming

-Failure to use proper analytic and statistical techniques

B. COMBAT SINMULATION WITH JANUS

1. Janus Background

Janus is a wargaming simulation. Named for the two-faced Roman god, who was the guardian of portals and the patron of beginnings and endings, Janus existed in several versions. Janus (L) was developed initially as a nuclear effects modeling simulation by the Lawrence Livermore National Laboratory of the University of California, but was also used for tactical training. Janus(T) was developed for Army combat development needs by the Training and Doctrine Command (TRADOC), Training Analysis Command (TRAC) activity,

White Sands Missile Range. Janus (A), simply known as Janus, represents a refinement of Janus(T), intended to satisfy both the combat development and training communities. [Ref. 7] Today, Janus exists and is used by the Army as Janus 7.0[1].

2. Characteristics of Janus

Using Janus, we seek to evaluate the tactical effectiveness of the Amphibious Assault Vehicle (AAV) in a simulated mined littoral region. Written in FORTRAN and adapted for use with the UNIX operating system, Janus is a high resolution, interactive, six-sided, closed, stochastic, ground combat simulation featuring precise color graphics. The high resolution allows the user to create individual infantry personnel and place them in combat scenarios. The interactive aspect allows the user to change a combat scenario during play. Up to six sides may be simulated. The scenario simulation is closed so that the disposition of opposing forces is relatively unknown to the players prior to starting the simulation. The locations may be identified later through intelligence created as detection occurs during the simulation. The system is

[1] This research used the prior release, Janus 6.88.

stochastic because it determines the results of actions according to the laws of probability and chance. [Ref. 7]

3. Features and Capabilities

Janus simulations use digitized terrain maps developed by the Defense Mapping Agency, now know as the National Imagery and Mapping Agency (NIMA). Each terrain map is a computer reproduction of actual terrain and is displayed in military format using the Universal Transverse Mercator grid system. These terrain maps realistically model terrain contour, roads, vegetation, water and other obstacles. Janus also simulates the effects of light and weather. Also buildings, fences, generic areas, and generic strings can be represented. Generic areas can be used to represent swamps, no-go areas, etcetera. Contour lines are brown, rivers and bodies of water are blue, roads are brown or gray with white outlines, urban areas are yellow, vegetation is green. Fences are red, generic areas and strings can be various colors. These factors all affect system movement, visibility, and target acquisition and must be considered when planning a scenario. [Ref. 7]

The user plans the scenario and controls the battle with a digital interface control. The user may task organize units and place them in defensive positions or put them in an offensive posture. Units may be in full

defilade, partial defilade, or put in prepared fighting positions. The user may designate movement routes from one position to another and plan movements starts and stops at specific times in the scenario. These routes and times may be altered at any time in the scenario before execution. Units on the move are in an exposed status but automatically go into partial defilade after stopping. Any weapons system's, whether on the move or stationary, may be placed in holdfire status. This capability allows the user to plan and direct fire on command. [Ref. 7]

The user may designate some vehicles as troop carriers and mount or dismount them on command. The user may create minefields and simulate other man-made obstacles such as abatis, ditches and craters. Engineer vehicles may be equipped to breach and clear these minefields and obstacles. The user may also create artillery and mortar systems and plan indirect fire missions. Other systems may be designated as smoke generators that may be used to simulate the obscuration effects of smoke on the battlefield. [Ref. 7]

Janus is a versatile tool which allows the user to create, duplicate, and alter scenarios at will. The database has an extensive library of available military components the user can choose and manipulate to create

scenario of his/her liking. The Janus database has three major sections: combat systems, terrain maps and symbols, and testing and analysis. The user is able to alter, duplicate and create scenarios within the combat systems database. In the terrain maps and symbols section, the user can edit, create and alter map terrains along with creating and altering symbols; the user may also create map overlays for use in wargaming. For testing and analysis, the user puts systems and terrains into a scenario in which the systems associated tactics can be tested. The user can then collect and analyze the data through the post processor.

C. USING JANUS TO MEET RESEARCH OBJECTIVES

This thesis utilizes Janus in evaluating the tactical effectiveness of the Amphibious Assault Vehicle (AAV) in mine countermeasure operations in the surf zone and beach zone.

1. Janus Advantages

In order to meet the research objectives, three scenarios were created using Janus. Janus allows the user to simulate identical environments in multiple scenarios so that a comparative analysis of each tactic or approach may be analyzed. The effects that may come about through minor environmental changes can be measured with the use of Janus. Janus allows the user to manipulate the environment as

required in each scenario. The data can be used to assist in the determination of whether a system or tactic is feasible or cost efficient.

2. Scenarios of Interest

The scenarios developed to meet the research objectives are:

--Bull Breaching: an amphibious landing through a minefield in the surf zone and beach zone (sz/bz) with no breaching operations.

--Traditional: an amphibious landing through a minefield in the (sz/bz) with current mine countermeasure assets being used for breaching.

--AAVs only: an amphibious landing through a minefield in the (sz/bz) using AAVs as the only breaching means.

D. JANUS MINES AND MINEFIELDS

1. Minefields and Their Depths

Janus allows for the simulation of five minefield types: (1) Hand Emp, mines laid by the hands of infantry or engineers; (2) Mech-1, mines laid by ground vehicle(s), pre-emplaced; (3) Artillery, mines laid by a vehicle(s) that have the capability to disperse a large number of mines also known as FASCAM (Family of Scatterable Mines); (4) Mech-2, mines laid by helicopter and/or ground vehicle emplaced; Mech-3, mines laid by a manually operated portable minelayer (MOPPM). The Janus code allows for a maximum of fifty minefields, provided that the total number of mines does not

exceed 80,000. In Janus each mine is individually placed on the terrain. There can be only one type of mine specified for each type minefield. [Ref 7]

Janus was created for land combat simulations. To create littoral scenarios with minefields, the user must manipulate the probabilities of detection and activation within the Performance Editor database. It is assumed that with the detection and activation values given, the user has created the land and littoral conditions required. The dimensions of each minefield may be altered within the Performance Editor database. Figure 2 illustrates the minefield used for the scenarios. Janus also allows the user to create and keep track of a maximum of 600 breach lanes.

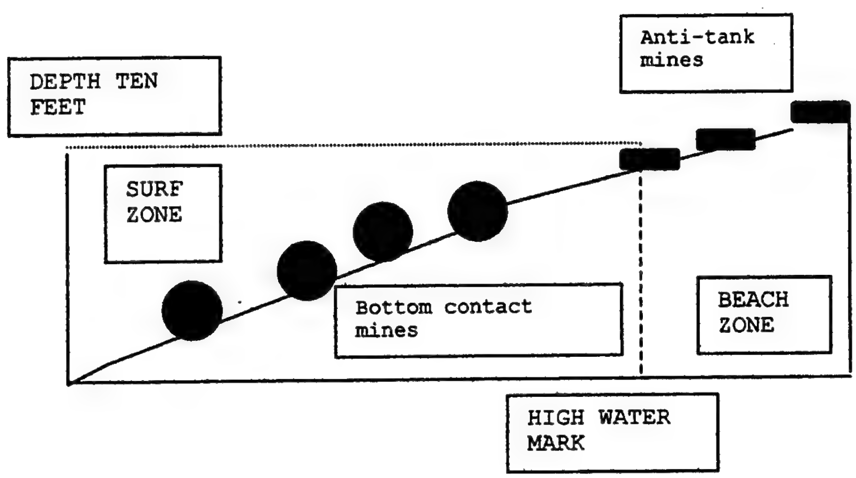

Figure 2

2. Mine Types

For the purpose of this thesis the Hand Emp and Mech-1 minefields will be used. The Hand Emp minefields will be minefield type 1 and they will be used in the sz and designated as bottom contact mines. The Mech-1 minefield will be minefield type 2, they will be used in the sz and/or bz primarily as anti-tank mines.

A single Hand Emp minefield consists of 99 mines. The mines within this minefield are located in three strips of 33 mines each. There is a distance of 15 meters between each strip. For every scenario run, the placement of the mines along each strip is randomly distributed. Hand Emp minefields are deployed by the user during the initial planning phase of each scenario. If the number of minefields is not changed within the database prior to each run, the minefields remain in their last saved location. The number of Hand Emp minefields desired per side is generated by entering the number into the Mine-1's field on Janus Screen III (for the respective side), not to exceed a total of 100 minefields.

Mech-1 employed minefields consist of mines that are uniformly random distributed in both length and width within the rectangular minefield. The length and width of Mech-1 minefields can be altered and set by the user. The user may

minefields can be altered and set by the user. The user may choose either low (40 mines), medium (80 mines), or high (160 mines) density. Although the length and width of this minefield can be altered, the number of mines is hard-coded. The user must position the minefield during the initial planning phase. The user also has the option to orient each minefield. This minefield is positioned and oriented by the user during the initial planning phase.

3. Minefield Densities

Each lane will consist of two Mech-1 minefields of dimensions 150 meters wide and 100 meters long. The lanes extend from the beach zone to approximately 225 yards out into the surf zone. Three Hand Emp mines were placed on the bz adjacent to each other. The Mech-1 minefields each contained 160 mines and the Hand Emp minefields each contained 99 mines. Consequently each lane consisted of 617 mines. This scenario should fulfill a worst case scenario. Figure 3 illustrates the littoral region of the minefields and their layouts.

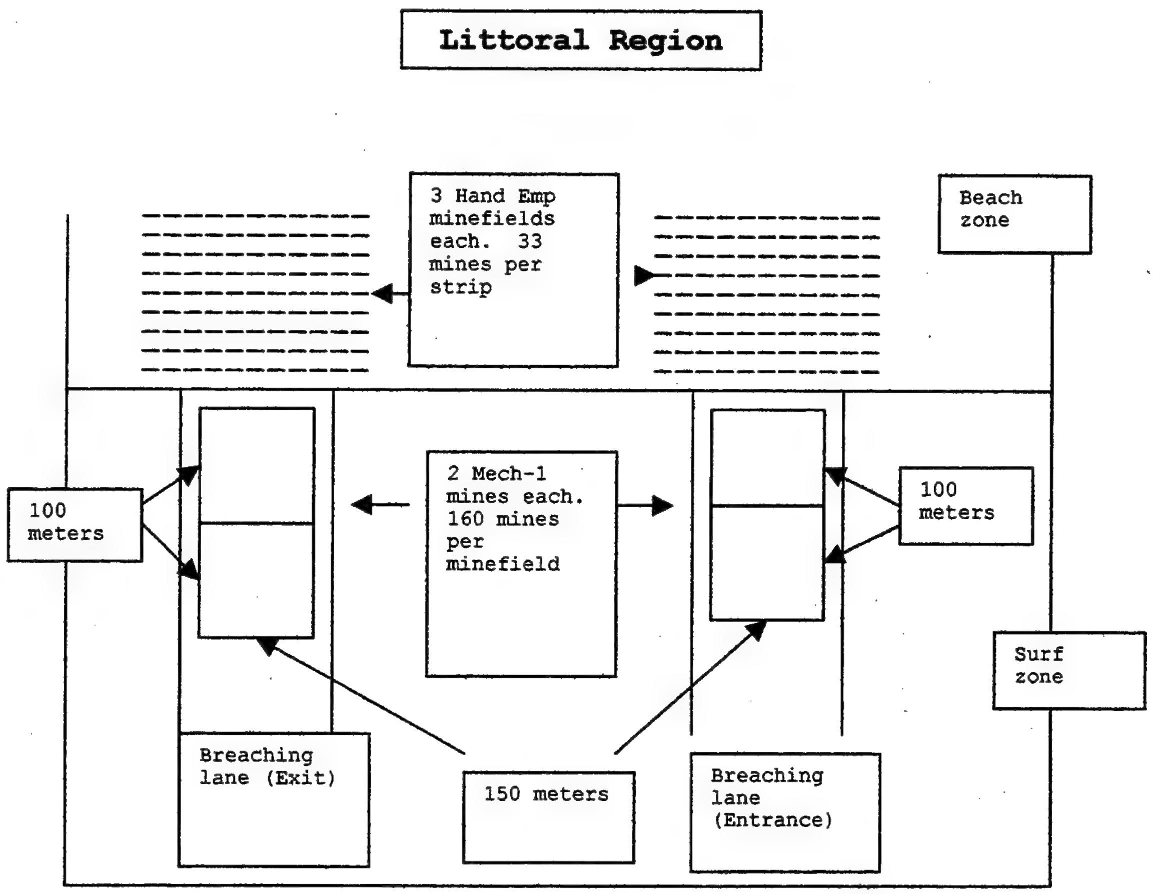
Littoral Region
3 Hand Emp minefields each. 33 mines per strip
Beach zone
100 meters
2 Mech-1 mines each. 160 mines per minefield
100 meters
Surf zone
Breaching lane (Exit)
150 meters
Breaching lane (Entrance)

Figure 3

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III. KERNEL BLITZ - 99

A. EXERCISE KERNEL BLITZ 99 SCENARIO

Kernel Blitz (KB) was intended to be an umbrella exercise for a series of naval force operational assets that occurred during the second/third quarters of fiscal year 1999 (FY 99) on the West Coast of the United States (U.S.). The KB scenario is based upon the littoral operations of U.S. Military forces against a representative Third World country. The operations span the low- to mid-intensity portion of the conflict spectrum. The geopolitical situation is representative of that which could occur in the year 1999 in a sensitive region with the initiation of hostilities leading up to and including the implementation of a Contingency Plan (CONPLAN) for that region. This thesis will focus on the amphibious assault portion of the KB exercise.

E. SCENARIO GEOGRAPHY AND BACKGROUND

The KB 99 exercise used a geographical area of land that comprised the states of California, Arizona and Nevada. For the purposes of this thesis the scenario will be conducted on digitized terrain the same to that of the

United States Marine Corps Base, Camp Pendleton. This region will involve two notional states.

C. SCENARIO DEVELOPMENT

1. Bull Breaching Scenario

The Bull Breaching Scenario simulates an amphibious landing through mined littoral zones without any breaching operations being conducted prior to assault. The intent of this scenario is to gauge the effect that heavily mined littoral zones would have on an amphibious assault being conducted without breaching operations. The data generated from this scenario will serve as a baseline for comparative analysis with the other scenarios of interest. [Ref. 3] A more detailed focus will be placed on the observations gathered from this scenario and the scenario in which the AAVs will be the only means of MCM.

2. Traditional Scenario

The Traditional Scenario is an exact copy of the Bull Breaching scenario, except that prior to the assault, minefield breaching is conducted in the sz/bz regions. Two lanes will be cleared, one for entering the beach and one for departing the beach. The assets used for this breach include the following:

- Four MH-53E Sea Dragon Helicopters towing MK 105 magnetic mine sweeping hydrofoils.

• Two AAVs equipped with MK 155 Launcher, Mine Clearance (LMC) kit (Abbreviated AAVLC for the purposes of this thesis.

• Four AAVPs equipped with mine clearing plows used to proof the lanes cleared by the line charges.

The sequence of breaching operations will go as follows:

1. Two Sea Dragons per lane will sweep the very shallow water clearing two 150-meter wide lanes.

2. One AAVLC per lane will fire its line charges clearing a lane 100 meters long by 160 meters wide.

3. Two AAVPs per lane follow the AAVLCs to ensure lanes are cleared of live mine and the AAVPs widen the lanes if possible.

3. Amphibious Assault Vehicles only Scenario

The AAVs only Scenario is an exact copy of the Traditional Breaching scenario, except that AAVLCs and AAVP will be the only means of MCM operations being conducted prior to the assault. Two lanes will be cleared, one for entering the beach and one for departing the beach. The assets used for this breach include the following:

• Eight AAVLCs

• Four AAVPs equipped with mine clearing plows used to proof the lanes cleared by the line charges.

The sequence of breaching operations will go as follows:

1. Two AAVLCs will proceed in each lane, firing its line charges clearing the first 100 meters long by 160 meters wide of the transit and exit lanes. Once all their line charges have been fired, they will depart the area.

2. The next two AAVLCs enter the lanes and complete the lane clearing.

3. Two AAVPs per lane follow the last AAVPs to ensure lanes are cleared of live mines and the AAVPs will widen the lanes if possible.

D. MEASURES OF EFFECTIVENESS (MOEs)

1. MOE 1 (Time required to complete the breach)

This MOE analyzes the time used to complete a breach. The length of time required to complete a breaching operation can effect the battle in various ways. The time factor can effect the buildup, support of, or retreat of enemy forces.

2. MOE 2 (MCM assets killed)

This MOE analyzes the number MCM assets killed while conducting breaching operations. The number of MCM assets required, with the breaching methods used, may be identified based on the number of MCM units immobilized.

3. MOE 3 (Neutralization of Mines)

The number of mines neutralized versus expected number of mines per landing lane will be analyzed. The method by which the mines were neutralized will be considered with this MOE.

E. CHAPTER SUMMARY

This chapter has described the scenarios and amplified their development. Chapter IV will present a statistical analysis of the numerical data results obtained from the execution of these scenarios.

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IV. DATA ANALYSIS

A. ANALYSIS CONCEPT

This chapter provides a statistical analysis of the data obtained from the Janus scenario runs. As discussed earlier, Janus uses stochastic simulations to determine the results of actions within a run. Furthermore, Janus produces outputs that are random and must, therefore, be treated only as an estimate of an action or effect that may result from a real life model or scenario. Due to the random variability with each scenario, one run would not depict the full range of possible outcomes. A total of ten runs were conducted with each scenario due to time constraints and to capture a range of possible outcomes.

Data collection is accomplished using the Janus Post Processing program. As a scenario runs, Janus records all the data compiled during the run: artillery impacts, direct fire shots, movement routes and kills, for instance. The Post Processing option permits you to generate printed reports, Killer-Victim scoreboards, for example, from those records. [Ref. 7] Within the Post Processing program is the Coroner's Report and the Minefields Report, which this thesis will use to analyze each scenario with respect to each MOE.

B. SCENARIO ANALYSIS

An analysis of the post-processing data generated from each of the scenario runs is conducted in this section. A total of ten AAVs was used for Scenarios 1 and 3 (Bull Breaching and AAVs only), with five AAVs breaching each lane. Scenario 2, the Traditional Breaching Scenario, utilized six AAVs (3 per lane), and two MH-53Es per lane.

Boxplots and tables, respectively, illustrate and list the data generated for each run as well as for the scenarios. In addition, the Wilcoxon Rank-Sum test is used to statistically analyze the data. The Wilcoxon Rank-Sum test is discussed in subsection C of this chapter.

Boxplots, a pictorial summary, describe several of a data sets most prominent features. The features include the center of the data, the spread of the data, the extent and nature of any of the departure from symmetry, and identification of any outliers, observations that lie unusually far from the main body of the data. Because even a single outlier can drastically affect the value of some numerical summaries, a boxplot is based on measures that are resistant to the presence of a few outliers. [Ref. 8]

Sample Boxplot

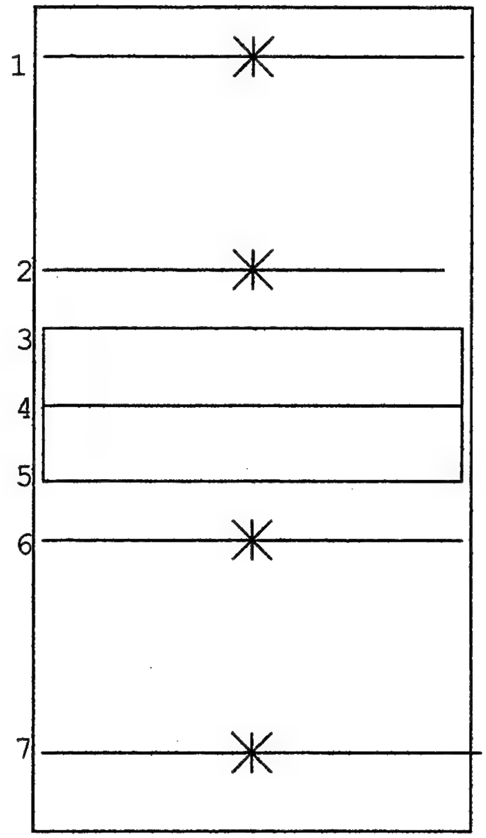

Figure 4

1. Extreme outlier: 3 times interquartile range
2. Mild outlier: 1.5 times interquartile range
3. Upper quartile or upper fourth: 75% of the data lies below this value
4. Median: 50% of the data lies below this value
5. Lower quartile or lower fourth: 25% of the data lies below this value
6. Mild outlier: 1.5 times interquartile range
7. Extreme outlier: 3 times interquartile range

1. Bull Breaching Scenario

a) MOE 1 (Time required to complete the breach)

Table 1 contains a listing of times an each AAV entered a minefield until the time it was destroyed or exited the last minefield. If the AAVs did not complete the breach due to its destruction, that destruction time was used as their completion time. The life span of an AAV will be considered the time it entered a minefield until the time it departed the minefield, or was killed within the minefield. The path of each AAV through the minefields remains the same for each run. Time was not considered a major aspect of analysis for this thesis, but time will be considered in conjunction with assets used, and how they are used. The range of an AAV's life span ranged from zero seconds to four minutes. It is believed that due do the randomness of the mine placements for each run that the shorter life span averages were due to mine clusters along the paths, and the opposite for the longer life spans. The average life span of an AAV was 1:33.

LIFE SPAN OF THE AAVs

Run Number	AAV 1	AAV 2	AAV 3	AAV 4	AAV 5	AAV 6	AAV 7	AAV 8	AAV 9	AAV 10	AVG
1	:24	2:45	1:30	1:06	2:33	1:29	1:53	1:11	2:04	:06	2:33
2	1:07	1:33	2:02	2:12	:54	:09	1:54	:06	1:54	1:36	1:21
3	1:18	:15	1:06	:12	:24	1:05	2:02	:06	:39	1:09	:49
4	1:52	1:09	:42	1:39	2:12	1:33	1:21	1:06	1:58	1:15	1:29
5	1:06	1:18	:39	1:00	:12	:18	1:00	:21	:51	:36	:44
6	2:18	:30	:42	4:06	2:10	:51	:54	2:30	2:03	:15	1:32
7	1:33	4:36	2:13	:45	:21	:48	2:27	:15	:12	4:04	1:43
8	3:18	1:51	:48	2:54	2:33	2:12	2:54	3:00	2:30	:06	2:10
9	2:09	:12	:24	2:09	0:0	2:09	1:53	2:09	:51	:33	1:15
10	:24	2:22	2:22	:30	2:12	:22	1:39	:49	4:21	4:09	1:55
									Avg. Life Span		1:33

Table 1

b) MOE 2 (MCM assets killed)

Table 2 contains data collected from the Coroner's Report. The focus here is on the number of AAVs killed. There were five AAVs per lane conducting breaching operations. In each lane (one entrance lane and one exit lane), the AAVs proceed from seaward toward the beach. It is expected that the number of kills in this scenario will be the highest of the three scenarios. There were 617 mines per lane. The average percentage of MCM assets killed was 81%.

AAVs KILLED (TOTAL OF TEN AAVs)

Run Number	No. of AAVs Killed
1	8
2	9
3	10
4	7
5	10
6	7
7	8
8	7
9	10
10	5
Avg # Killed	8.1

Table 2

c) MOE 3 (Neutralization of mines)

Table 3 contains the number of mines neutralized per run. The destruction of an AAV will also be considered as neutralizing a mine(s). During one of the runs, it was observed that an AAV entered a lane/minefield and was immediately destroyed. With its destruction, it destroyed along with it approximately twelve mines. With the randomness of the mines within the minefield, other mines were destroyed due to their proximity to an exploding mine. Recall that each lane contains 617 mines. The first set of minefields in each lane contained 160 mines each within a 100 by 150-meter rectangle. The average number of mines neutralized was 37.37%.

THE NUMBER OF MINES NUETRALIZED

Run Number	Entrance Lane	Exit Lane	Total
1	378	152	530
2	350	224	574
3	0	199	199
4	144	274	418
5	258	282	546
6	230	137	367
7	153	191	344
8	315	282	597
9	142	197	339
10	348	350	698
		Avg # Neutralized	461.2

Table 3

2. Traditional Scenario

a) MOE 1

Table 4 is identical to table one of the Bull Breaching scenario. Recall that the MH-53Es will conduct breaching operations first, followed by two sets of AAVs per lane. Once the first set of AAVs complete their breaching operations or are destroyed, the second set will enter the lanes to try to complete the breaching operations. Typically, the time required to complete breaching operation would be vastly larger than the other two scenarios. However, the time will commence when the AAVs commence breaching operations. If the AAVs did not complete the breach due to their destruction, their destruction time was used as their completion time. Janus is configured so that AAVs with line charges required longer times to conduct breaching operations, as opposed to AAVs with plows. In run three it was observed that the AAVs were killed much quicker than the other run. It is believed that the locations of the mines in this run were in a more congested region of the AAVs paths. The paths for each AAV remained the same for each run. The average life span of an AAV was 10:00.

LIFE SPAN OF THE AAVs

Run Number	AAV 1	AAV 2	AAV 3	AAV 4	AAV 5	AAV 6	AVG
1	24:50	24:41	3:20	3:20	3:20	3:00	10:25
2	24:50	24:24	3:15	4:34	3:40	2:30	10:32
3	23:45	23:11	1:05	2:00	1:09	:51	8:40
4	24:00	22:59	3:10	3:15	3:15	3:30	10:02
5	25:00	24:27	3:15	3:15	3:15	3:24	10:26
6	24:40	24:15	3:10	2:37	3:40	3:35	10:20
7	25:40	23:34	2:50	3:00	2:30	2:30	10:01
8	24:40	23:40	2:15	2:15	2:15	1:50	9:29
9	24:00	23:29	3:10	3:10	3:10	3:00	10:00
10	24:30	23:33	3:00	2:55	3:00	3:00	10:00
					Avg. Life Span		10:00

Table 4

b) MOE 2

Table 5 contains the number of AAVs killed. The majority of the AAVs were killed within the beach zone. This was due to the loss of line charges. The loss of a line charge was due to the number of mines the AAV came into contact with. It was observed in several runs, some AAVs were not able to complete their breach due to the number of mines they came into contact with. Recall that the length of the total minefield was approximately 350 meters. Each AAV carried four line charges of 100 meters each. If an AAV encountered a larger number of mines early on, it typically lost its breaching capability towards the end of the minefields, increasing its probability of being killed. The average number of AAVs killed was 35%.

AAVs KILLED (TOTAL OF SIX AAVs)

Run Number	No. of AAVs Killed
1	1
2	3
3	3
4	2
5	2
6	2
7	2
8	3
9	1
10	2
Avg # Killed	2.1

Table 5

c) MOE 3

Table 6 lists the number of mines neutralized with the use of AAVs and MH-53Es. It was expected this scenario would have the best percentages of mines neutralized. The destruction of an AAV will also be considered as neutralizing a mine(s). With the randomness of the mines within the minefield, other mines were destroyed due to their proximity to an exploding mine. Recall that each lane contains 617 mines. The average number of mines neutralized was 1017.8. Runs 3, 7 and 8 together yielded an average of 100 less mines neutralized than the average. The only conclusion that can be drawn from this observation is the clustering of the mines, or lack there of, along the paths within the minefields. The average percentage of mines neutralized by MH-53Es was 32%; a MH-53E averaged 100 mines cleared per run, and the average by AAVs was 50.08%, for an overall average of 82.48%.

THE NUMBER OF MINES NUETRALIZED

Run Number	By Helicopters	By AAVs	Total
1	405	790	1195
2	406	550	956
3	416	550	892
4	406	694	1100
5	411	619	1030
6	405	636	1041
7	421	497	918
8	395	498	893
9	414	781	1195
10	393	565	958
Avg # Neutralized	407.3	618.0	1017.8

Table 6

3. AAVs only Scenario

a) MOE 1

Table 7 is identical to tables one and four. It was expected for the times in this scenario to be of greater extent due to the use of breaching with line charges by eight of ten AAVs in this scenario. Recall an AAV conducting MCM with a line charge will take a substantial amount of time in comparison to an AAV using a plow to conduct breaching operations.

Again, the path of each AAV through the minefields remained the same for each run. The life span of an AAV was considered the time it entered a minefield until the time it departed the minefield, or was killed within the minefield. Recall, the first AAVs cleared a portion of the lanes (approximately 150 meters of 350 meters of minefields), departed the lanes along their entrance path, and the second set of AAVs entered the lanes and continued breaching operations, followed by the last set of AAVs. The first two sets of AAVs used line charges and the last set used plows. The life span of several AAVs was shortened due to the vast number of mines they came into contact with. The average life span of an AAV was 16:47.

LIFE SPAN OF THE AAVs

Run Number	AAV 1	AAV 2	AAV 3	AAV 4	AAV 5	AAV 6	AAV 7	AAV 8	AAV 9	AAV 10	AAV 11	AAV 12	Avg. per run
1	32:13	25:25	25:27	26:30	21:35	23:57	24:29	28:08	2:43	3:33	2:59	3:22	18:22
2	17:22	25:20	29:22	29:22	6:08	24:45	19:36	21:37	4:18	3:13	3:12	3:42	15:40
3	31:03	13:11	13:13	13:18	13:16	15:42	21:11	31:12	4:04	4:26	3:06	3:07	13:54
4	33:08	16:27	14:11	14:10	13:27	22:25	21:37	33:09	2:55	4:07	2:51	2:51	15:06
5	31:34	16:15	25:03	16:09	15:15	29:40	21:50	30:32	3:25	3:26	3:24	3:59	16:43
6	27:35	21:51	21:53	22:42	22:48	20:08	15:51	22:46	5:54	5:42	6:03	6:42	16:40
7	31:05	28:29	28:31	13:50	13:50	22:18	18:26	30:22	5:18	5:26	4:45	4:21	17:13
8	31:45	29:12	29:45	15:41	15:50	13:36	18:47	29:34	2:11	11:34	1:34	1:37	15:56
9	32:00	12:17	31:20	33:00	33:00	27:22	18:00	24:20	3:18	2:18	3:10	3:18	18:37
10	32:40	30:30	30:30	31:20	31:20	25:48	15:03	26:50	2:55	2:50	3:05	3:10	19:40
											Avg. Life Span		16:47

Table 7

b) MOE 2

Table 8 is identical to tables two and five. The kill ratio for this scenario was expected to be the lowest of the three scenarios, due to the use of the shortened paths of the first set of AAVs. It was surprising to see the number of AAVs killed from the second and third sets of AAVs. Recall there were five AAVs per lane conducting breaching operations. In each lane (one entrance lane and one exit lane), the AAVs proceeded from seaward toward the beach. The first set of AAVs entered the lanes/minefields for approximately 150-meters, turned around and continued breaching operations. The average number of deaths during the first set of runs was less than one AAV.

If we hypothetically looked at the first 150 meters of minefield being cleared by the first set of AAVs, that would leave approximately 457 mines for the remaining sets of AAVs to clear. Therefore, it was expected that the last two sets of AAVs would easily complete the breaching operations with little to no losses of AAV assets. The second and third set of AAVs continually lost their breaching capability for each run. Recall an AAV will lose its breaching capability if it continually encountered mines along its path. The average number of AAVs killed was higher than expected. The percentage of AAVs killed was 36%.

AAVs KILLED (TOTAL OF TEN AAVs)

Run Number	No. of AAVs Killed
1	4
2	4
3	3
4	3
5	3
6	4
7	4
8	4
9	4
10	3
Avg # Killed	3.6

Table 8

c) MOE 3

Table 9 lists the number of mines neutralized with the use of AAVs only. The destruction of an AAV will also be considered as neutralizing a mine(s). With the randomness of the mines within the minefield, other mines were destroyed due to their proximity to an exploding mine.

As expected, the average number of mines neutralized was the largest of the three scenarios. However, the percentages of mines neutralized between this scenario and the Traditional are relatively close. Although, the number of mines neutralized was greater, the number of AAVs killed was higher than expected, as explained in section b of this scenario. The average percentage of mines neutralized was 83.46%.

THE NUMBER OF MINES NUETRALIZED

Run Number	Entrance Lane	Exit Lane	Total
1	511	548	1059
2	596	504	1100
3	497	482	979
4	558	501	1059
5	609	554	1163
6	558	432	990
7	526	461	987
8	524	438	962
9	585	425	1010
10	604	386	990
	Avg # Neutralized		1029.9

Table 9

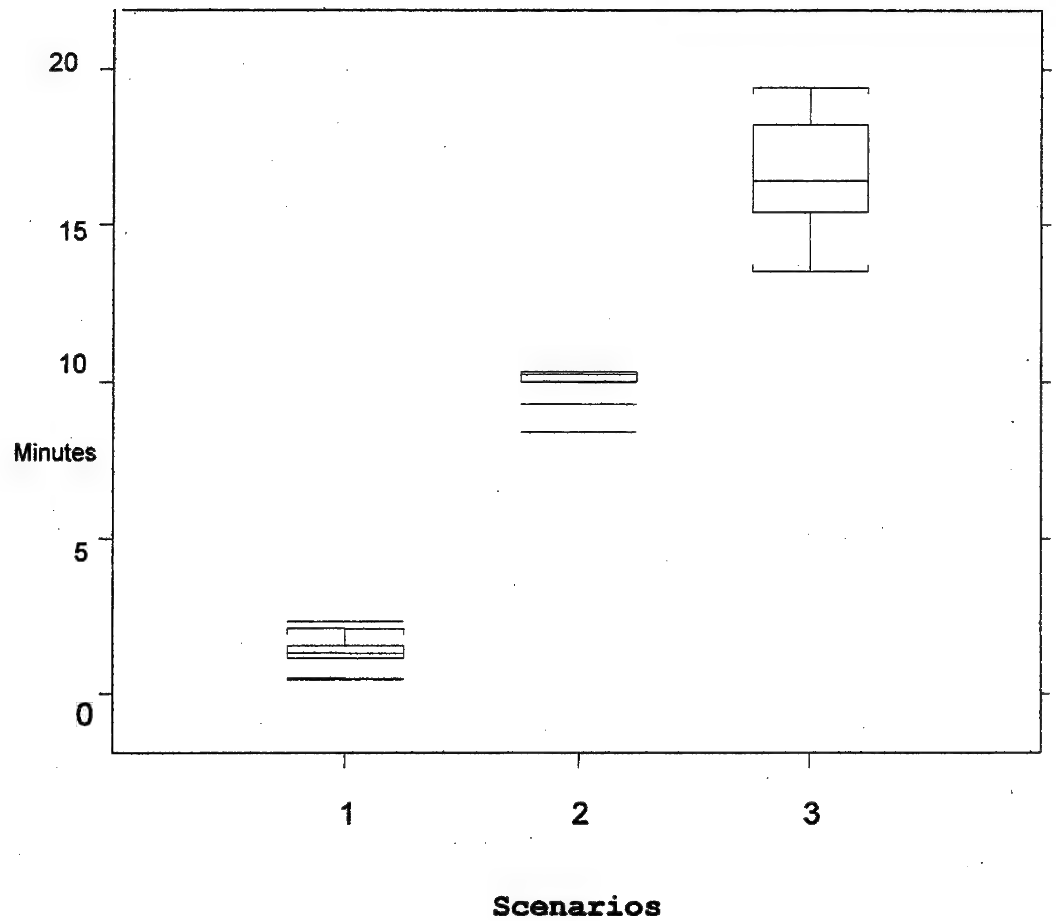

Figure 5, X-Axis represents Boxplots of Life Spans for Scenarios 1,2,3 respectively

Boxplot 1 shows an average of 1:33, with mild outliers at 44 and 49 seconds and an extreme outlier at 2:33. Boxplot 2 is very tight ranged around the median of ten minutes. There are mild outliers at 8:40 and 9:29. Boxplot 3 has a much broader range of values ranging from 15:06 to 18:22, and a median at 16:47. The maximum and minimum

values represent the mild outliers. There is a very small variation in scenarios 1 and 2 as compared to a greater variety of average times for scenario 3. There was no surprise to the compactness of the average life spans for scenarios 1 and 2 because of the MCM methods used. The larger variability of average life spans within scenario 3 was noted within the description of MOE 1.

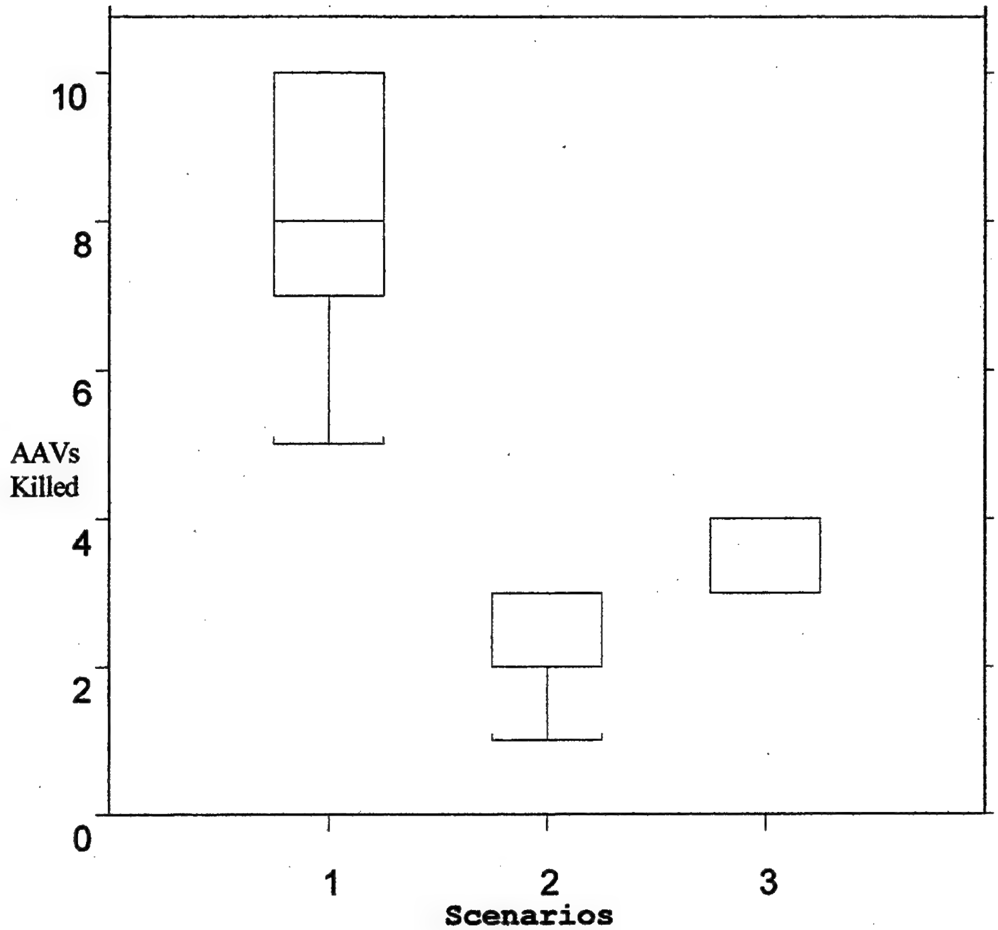

Figure 6, X-Axis represents Boxplots of AAVs Killed for Scenarios 1,2,3 respectively

Boxplot 1 shows an average of slightly over eight AAVs killed per run for Scenario 1, with an outlier shown at five AAVs killed. Boxplot 2 shows an average of approximately two AAVs killed per run for Scenario 2. Approximately 75% of the AAVs killed per run were below three. With a mild outlier at one AAV killed. Box 3 displays Scenario 3's

average number of AAVs killed. It shows a consistent number of AAV kills, between three and four.

The medians for scenarios 2 and 3 are relatively close, while the medium for scenario one is considerably larger. The average number of kills for scenarios 2 and 3 remained within a small group. Scenario 1 has a larger spread for the average number of kills. As stated in the description of MOE 2, the range in distributions may be caused by the randomness of having mine clusters along the paths of each AAV within each run.

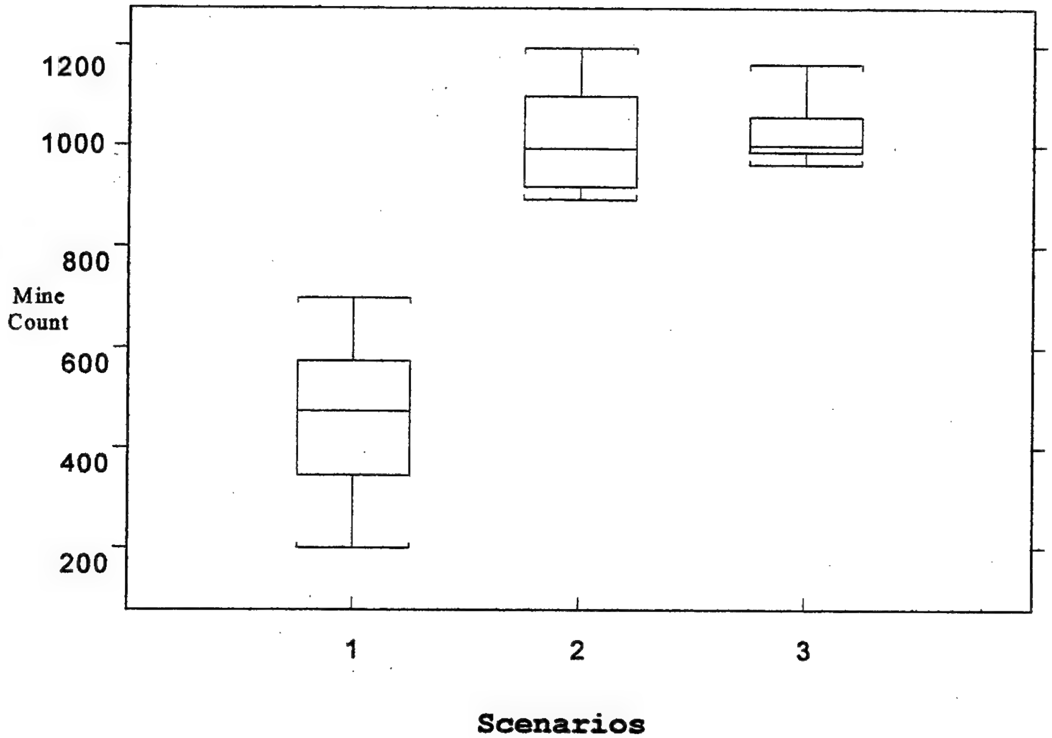

Figure 7, X-Axis represents Boxplots of the Mines Neutralized for Scenarios 1,2,3 respectively

Boxplot 1 illustrates the number of mines neutralized in Scenario 1, with an average of 461.2 mines neutralized. The distribution is consistent with approximately 350 to 590 mines neutralized. There were extreme outliers at 698 and 199 mines neutralized. Boxplot 2 illustrates the number of mines neutralized in Scenario 2, with an average of 1017.8 mines neutralized. There were mild outliers at 892 and 893 mines neutralized, and two extreme outliers at 1195. Boxplot 3 illustrates the number of mines neutralized in

Scenario 3, with an average of 1029.9 mines neutralized. There were mild and extreme outliers at 1100 and 990.

The median for scenarios 2 and 3 are similar and large, as expected due to the number and type of assets used. It was not expected that scenario 2 would have as large a number of mines cleared as scenario 3, because the number of assets using line charges was less in scenario 2 than scenario 3. Scenario 2 had such an increase do to the MH-53Es clearing an average of 400 mines per run.

C. WILCOXON RANK-SUM TEST

The Wilcoxon Rank-Sum test is a nonparametric test for the comparison of two populations when only small independent samples are available and the populations from which they are selected are not necessarily normal. The Mann-Whitney test is an alternative name for the procedure. The Mann-Whitney test statistic is sometimes expressed in a slightly different form from that of the Wilcoxon test. The Wilcoxon test procedure has the significance for a very large class of underlying distributions and is therefore distribution-free. [Ref 8] The Wilcoxon Rank-Sum test is generally considered a more valuable significance test than is the sign test or median test because it uses more information. The forerunner of the Mann-Whitney test, having been developed by Wilcoxon (1949) for speedy

assessment of differences of matched or related samples, is the Wilcoxon test. [Ref 9] The null hypothesis is:

> H_0: The population distributions are identical (i.e., there is no difference in the effectiveness of the two (paired) MCM methods).

The effectiveness of the different MCM methods is measured as a function of the number of mines neutralized per scenario. The alternative hypothesis ($H_{1,2,3}$) is that at least one population distribution is different from one of the other population distribution. When using the Wilcoxon Rank Sum test, the scenarios will be analyzed in pairs against corresponding MOEs (i.e. MOE 1 of scenario 1 against MOE 1 of scenario 2, MOE 3 of scenario 1 against MOE 3 of scenario 3, etc.). The alternative hypotheses are:

> H_1: Traditional is more effective than Bull Breach
> H_2: AAVs only is more effective than Bull Breach
> H_3: AAVs only is more effective than Traditional

A significance level, α, of 5% was used for an analysis of each MOE because it is the standard for this type of test. This statement basically states that with an α less than five percent in an MOE, the null hypothesis will be rejected. The significance level acts as a cut-off point below which we agree that an effect is statistically

significant. It is a fixed probability of wrongly rejecting the null hypothesis H_o, if it is in fact true. In other words, with a 5% significance level, there is a 5% chance of rejecting the null hypothesis though it may be true. If p-value is less than or equal to α, then we rule out the null hypothesis H_o. The statistics package used in this study was S-Plus. The results of the Wilcoxon Rank-Sum tests for each MOE are given in tables 10, 11, and 12.

Scenario Paring	**P-Value**	**Reject H_0**
Traditional and Bull	.0002	Yes
AAV only and Bull	.0000	Yes
AAV only and Traditional	.0002	Yes

Table 10, Wilcoxon Rank-Sum Test Results for MOE 1

Table 10 summarizes the Wilcoxon Rank-Sum test for MOE 1. It can be concluded that there is a significant difference in time between each comparison. This is obvious through analysis of figure 5, the boxplots of MOE 1.

Scenario Paring	**P-Value**	**Reject H_0**
Traditional and Bull	.0002	Yes
AAV only and Bull	.0001	Yes
AAV only and Traditional	.0006	Yes

Table 11, Wilcoxon Rank-Sum Test Results for MOE 2

Table 11 summarizes the Wilcoxon Rank-Sum test for MOE 2. It can be concluded that there is a significant difference in AAVs killed between the first two comparisons. I was surprised by the low p-value for the last comparison. I expected the value to be much closer to the significance level due to the minor difference in averages of killed AAVs.

Scenario Paring	P-Value	Reject H_0
Traditional and Bull	.0002	Yes
AAV only and Bull	.0002	Yes
AAV only and Traditional	.4956	No

Table 12, Wilcoxon Rank-Sum Test Results for MOE 3

Table 12 summarizes the Wilcoxon Rank-Sum test for MOE 3. It was expected that any scenario compared with Bull breaching (scenario 1) would be rejected due to their vast differences. As shown in figure 7, the number of mines neutralized was very similar. Therefore, the last comparison could not be rejected.

D. CHAPTER SUMMARY

This chapter has provided a detailed analysis of the data retrieved from Janus at the completion of all simulation runs. The following chapter will summarize the

results of this study and provide recommendations regarding the use of AAVs only as an efficient MCM method.

V. CONCLUSIONS AND RECOMMENDATIONS

The objective of this thesis was to evaluate the effectiveness of the use of Amphibious Assault Vehicles (AAVs) equipped with line charges and plows as the only means of mine countermeasures in the surf zone and beach zone (sz/bz). The objective was met by utilizing Janus to develop three scenarios to test and evaluate the differences in effectiveness of bull breaching a minefield, the use of a traditional method of MCM, and the use of AAVs only to breach a minefield. The Bull Breaching and AAV only scenarios were identical by their use of ten AAVs, but not by the MCM method employed. The traditional scenario used four MH-53Es towing MK-105 hydrofoils and six AAVs. The scenarios were executed ten times each, with data being generated by from run.

The analysis of each scenario was focused on the number of AAVs killed, the number of mines neutralized, and to a lesser extent, the time required to breach the minefields. A nonparametric statistical method was used to compare the three scenarios with regard to the time required to conduct breaching operations, the AAV assets killed, and the number of mines neutralized. This method sought answers to these questions:

1. Is Traditional a more effective MCM method than Bull Breaching?

2. Is AAVs only a more effective MCM method than Bull Breaching?

3. Is AAVs only a more effective MCM method than Traditional Breaching?

Assumptions that were made to develop and run the scenarios were:

- Mine types are bottom contact in the surf zone and anti-tank in the beach zone.
- Minefield densities were extreme.
- The AAVs were each capable of carrying four MK 155 Launcher Mine Clearance kits along with a crew.
- The AAVs were in good condition with no mechanical problems.
- The MH-53Es were in good condition with no mechanical problems.
- If an MCM asset was killed while in the minefields, the breaching operations would continue without the interruption of the killed asset.
- Demarcation lines of the minefields outer edges were marked.

It was also expected prior to the run of the scenarios that Bull Breaching would result in the greatest loss to MCM assets, the least number of mines neutralized, and the shortest amount of time used to breach the minefields. It was also expected that the Traditional MCM method would out

perform the Bull Breaching method, but not outperform the AAV only MCM method. It was believed that the AAV only scenario would neutralize a higher percentage of mines and have a lower count of AAV units killed. However, it was not expected that the Traditional and AAV only scenario would be as closely related as they were in the neutralization of mines and the percentage of AAVs killed.

From the analysis of the boxplots, the Wilcoxon Rank-Sum test, and summary of the data tables, the AAV only MCM method was considered the better means of MCM operations. Recall the AAV only MCM method averaged 16:47 minutes to conduct breaching operations, with 36% of its AAV assets killed, and 83.46% of the mines neutralized. The Traditional MCM method comparatively had similar results with an average of 10:00 minutes to conduct breaching operations, with 35% of its AAV assets killed, and 82.48% of the mines neutralized. Both mentioned methods were similar in their averages of AAV assets killed and the number of mines neutralized. The substantial difference between the two MCM methods was the average time required to conduct breaching operations, or in other words, the average life span of an AAV. Recall, the time required for the air assets, MH-53Es, to conduct MCM operations were not used, and that an average of 400 mines per run were neutralized by

the MH-53Es. The MH-53Es greatly assisted in the 'low' percentage of AAV assets killed and the high percentage of mines neutralized for the Traditional scenario by clearing approximately one-third of the mines.

Based on the above-mentioned results, I submit the AAV only scenario was effective as a mine countermeasure vehicle in both the surf zone and the beach zone.

The analysis suggests that the Traditional and AAV only are comparatively effective methods of breaching with the assumptions made. It also suggests that a combination of the mine clearing air assets, the substantial use of AAVs equipped with line charges, and the use of AAVs equipped with plows would be a very effective means of mine countermeasure operations.

The bottom line on breaching operations will be based on the time available to conduct MCM operations. It is important to restate that it is imperative for the Navy to find and neutralize every mine. For the Navy, the striking of a mine can be the loss of a vast amount of supplies, a major combat asset, or the loss of many sailors.

APPENDIX. DATA AND SUMMARY STATISTICS

	scenario1	scenario2	scenario3
Min. value:	0.44000	8.40000	13.54000
1st Quartile:	1.16500	10.00000	15.44000
Mean:	1.33100	9.87500	16.55100
Median:	1.30500	10.01500	16.41500
3rd Quartile:	1.52000	10.23750	17.94750
Max. value:	2.33000	10.32000	19.40000
Total N:	10.00000	10.00000	10.00000
Standard Dev.:	0.59605	0.59450	1.76949

Figure A1. Statistical analysis of MOE 1 (Lifespan of AAVs)

	scenario1	scenario2	scenario3
Min. value:	5.000000	1.000000	3.000000
1st Quartile.:	7.000000	2.000000	3.000000
Mean:	8.100000	2.100000	3.600000
Median:	8.000000	2.000000	4.000000
3rd Quartile:	9.750000	2.750000	4.000000
Max. value:	10.000000	3.000000	4.000000
Total N:	10.000000	10.000000	10.000000
Standard Dev:	1.663330	0.737865	0.516398

Figure A2. Statistical analysis of MOE 2 (AAVs killed)

	scenario1	scenario2	scenario3
Min. value:	199.000	892.000	962.000
1st Quartile:	349.750	927.500	987.750
Mean:	461.200	1017.800	1029.900
Median:	474.000	994.000	1000.000
3rd Quartile:	567.000	1085.250	1059.000
Max:	698.000	1195.000	1163.000
Total N:	10.000	10.000	10.000
Standard Dev.:	151.775	114.988	64.070

Figure A3. Statistical analysis of MOE 3 (No. of Mines Neutralized)

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